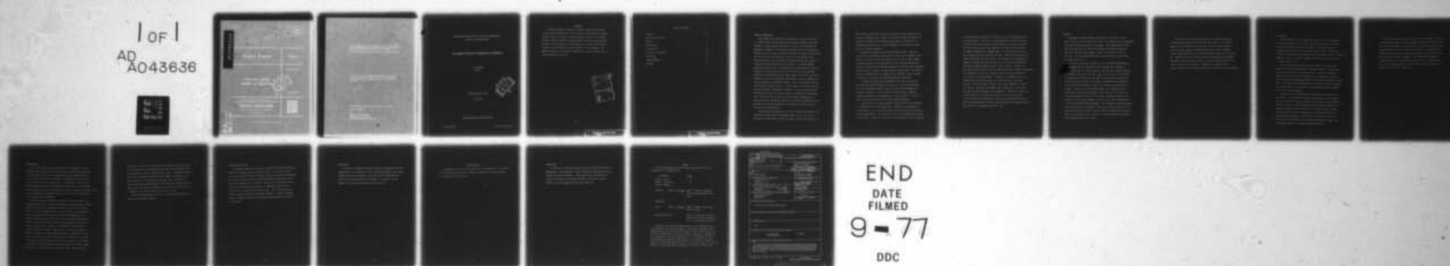
AD-A043 636 MASSACHUSETTS INST OF TECH LEXINGTON LINCOLN LAB F/G 22/2
A DYNAMIC SATELLITE SCHEDULING ALGORITHM. (U)
JUL 77 W J TAYLOR F19628-76-C-0002
UNCLASSIFIED ETS-15 ESD-TR-77-176 NL

1 OF 1
AD
A043636



END
DATE
FILMED
9-77
DDC

ESD-TR-77-176

See 1473

12

Project Report

ETS-15

W. J. Taylor

A Dynamic Satellite Scheduling Algorithm

7 July 1977

Prepared for the Department of the Air Force
under Electronic Systems Division Contract F19628-76-C-0002 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

Approved for public release; distribution unlimited.

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-76-C-0002.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt. Col., USAF
Chief, ESD Lincoln Laboratory Project Office

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

A DYNAMIC SATELLITE SCHEDULING ALGORITHM

W. J. TAYLOR
Group 94

PROJECT REPORT ETS-15

7 JULY 1977

LEXINGTON MASSACHUSETTS

ABSTRACT

A computer program to dynamically schedule satellite observations has been installed and tested. The principle of the program is to apply weighting factors for each of several pertinent criteria to the angular distance between the current telescope position and the current predicted position of each satellite in a predefined list. Initial tests showed favorable results with few large displacements of the telescope. The program executes in 5-7 seconds of shared real time for a typical mix of about one hundred satellites.

TABLE OF CONTENTS

SATELLITE SCHEDULING

The problem of scheduling the observation of a list of satellites in a fashion which reduces telescope slew between satellite encounters, attempts to acquire objects when they are likely to be detectable and minimizes the number of objects which "escape," either by setting or by entering a region of their orbit where they are not likely to be detected, has been of concern for some time. Before the installation of the Dynamic Scheduler, up to four hours of analysis per day was required to schedule the hundred-odd objects which appear in the Space Defense Center (SDC) tasking list. This analysis involved generating a printed ephemeris for each satellite on the list and line by line comparing ephemerides to determine the most likely target for a given time interval. Needless to say this was extremely tedious work. Once the schedule was written another set of problems followed. The static schedule allowed a fixed amount of time per object. If data taking on one object took less time than expected a "dead space" occurred. If it took more time then the observation time for the next object in the schedule was infringed upon. Worse still was the fact that should weather conditions in a certain portion of the sky be prohibitive of observing satellites there, no simple recourse was available to the operator to effectively fill this portion of the schedule.

Computerizing the production of a static schedule would involve the expenditure of many hours of development time in search of a way to optimize the schedule while trying to manage all the necessary data. It

was estimated that the run time for the scheduler could exceed one hour per day of computer time. Further, it would do nothing to alleviate the problems of dead space and overlap metioned above. Because of the shortcomings and expense of a static scheduler it was decided to write and test a dynamic scheduler.

Dynamically scheduling satellite observations means: given the current telescope pointing angles and the current time, determine which objects in a list are above the horizon, and for each of these compute the angular distance of the satellite from the telescope boresight and determine, based upon both orbital parameters and certain other information about the object, a weight for each satellite at that time. The angular distance is multiplied by the weight and the resultant "closest" object is offered to the operator as his next attempted acquisition.

A priority structure has been imposed on the selection process. Using the SDC tasking category as the priority it has been determined that all schedulable category 1 objects must be serviced before any category 2 object, etc. This hard cut-off rather than a weighting scheme was chosen at the recommendation of SDC personnel. It is felt that it best reflects the intent of the tasking categories.

The details of the weight computation are presented in the Appendix. All weights are arrived at empirically. Changes to the magnitude of a given weight by up to a factor of ten do not seem to affect the selection process significantly. The point here is that since weighting is applied to all objects in the list, the size of a given weight is not as important

to the selection process as is the relative size of the weights applied to various factors. That is, is it more important to service a setting satellite than a known payload; or more important to service one which has not been observed in a long time than one which has an old epoch? The weights computed by the program tend to be about the same size for most considerations with certain exceptions. These are the mean motion weight and the elevation rate weight. The biases used in computing the weights for element set age and time since last observation represent reasonable breakeven points for each of those criteria. Element sets less than ten days old are "new," but after that point it becomes increasingly more important to verify the satellite's position and to provide data for a new set of orbital elements. Similarly, if an object has been observed in the past three days, it is fairly certain to be easily acquired. After that time it becomes increasingly important to verify its location. Note well that objects whose element set is new or who have been recently observed are not handicapped. The view is taken that if the element set is relatively fresh, the objects have been seen recently and nothing remarkable is occurring with respect to the orbit, then the weighted angular distance should approximate the angular distance. The results of the program reflect this view.

RESULTS

The Dynamic Scheduler (DYNA) was installed at the ETS on 6 June 1977. Since it was written as a test bed for the algorithm, full integration into the real time system was not attempted. This simply means that RTS does not automatically activate and deactivate the program along with the rest of the real time programs. Hence, some operator action is necessary. But the program has access to all pertinent real time data and system data files.

The first on-line test of DYNA on 7 June 1977 GMT proved worrisome. The assumption had been made that the SDC tasking list contained a fairly uniform set of objects, some old, some new; most recently observed. Unfortunately this is not the case. Most of the objects in the list had old element sets (30-100 days old) and many had never been observed or had been observed long ago. As a result, the telescope was running all over the sky "fire fighting." Since it is really no more important to attempt to acquire a satellite whose element set is 100 days old and which has not been seen by the ETS in a year than it is to acquire an active payload which is close to the current telescope position, it was decided to place an upper bound of a factor of two (in the denominator) on the epoch and time observed weights. The difference in DYNA performance after the modification was marked. Seldom are telescope traverses of 60 degrees between objects made, typically only when moving from the Molniya belt to the synchronous belt or late in the evening when the population of schedulable objects gets sparse.

A hard cut-off on the sensor include solar illumination angle of 100 degrees was installed for the 11 June GMT session. No noticeable change in the selection process resulted. Had the session extended until near dawn, however, the program would have refused to attempt objects significantly east of the local meridian. This is as it should be. (Indeed, objects in the west early in the evening were undoubtedly excluded because of their sun angle. But since we were working in the east we failed to note the fact.) Subsequent to testing at site a region 30 degrees from the lunar position has been excluded from scheduling.

THE PROGRAM

When delivered to the ETS, DYNA contained all the logic necessary to initially specify, add to, delete from, and otherwise edit a list of up to 100 satellite numbers to be scheduled. A disk file has been provided for storage of the list and its current status. This file is read each time the scheduler begins execution and written each time execution completes. Hence in case of a computer or power failure, the list and its status are not lost.

Most of the editing functions have been moved to a stand alone Tasking File Update program which is run during the day. Editing time for the list is about one half hour per day. This can be reduced to perhaps five minutes per day if the SDC can be persuaded to publish a standard format tasking message instead of the narrative message currently sent. The standard format message could be computer processed (currently all changes to the list are typed) and only locally generated requests would have to be hand entered.

Some features of the program which provide great flexibility are the ability to: automatically restore certain objects to the schedule queue at the end of a certain time interval, change the time interval or deselect the option, deselect weighting, manually mark a satellite as scheduled, manually restore objects to the schedule queue (by number, all objects or all objects scheduled but not observed), change the tasking category (priority) of any object in the list, or list the satellites in the schedule either in descending satellite number order or descending priority (increasing tasking category).

The schedule queue contains the list of satellite numbers of interest, a tasking category and a time last scheduled associated with each. When a satellite is scheduled, the current time is entered into its time last scheduled and the satellite number is set negative. A listing of the schedule queue will put all scheduled satellites at the end of the list where they can be easily recognized. Since the satellite numbers of scheduled objects are not removed from the list it is a simple matter to restore the satellite number to the queue when either an automatic or a manual restore request is indicated.

PROBLEM AREAS

Most of the ticklish spots with regard to the program are in the boundary values. More to the point, what the scheduler would like to be able to compute is a truth value associated with the detectability of each satellite at the time of interest. "How bright is the satellite and can I expect to see a satellite of that brightness?" To know this, detailed information about the structure and orientation of the satellite and a reasonable model for the reflection of such a satellite are needed. Work on this modeling is an ongoing effort, but is not yet to the state where it is available to the scheduler.

Lacking information about the detectability of the satellite, the program simply tries to eliminate certain obvious problem areas. Already mentioned are the areas proximate to the moon and the sun in viewing angle. The most troublesome area is that of distance to the satellite. For all satellites, regardless of their reflection properties, the observed radiance varies as $1/R^2$, where R is the observer to satellite distance (radar slant range). Hence, knowing nothing else about the object, the point of least range is as reasonable a place as any to attempt to acquire the object. Hence, we do not wish to schedule an object at a range of 65,000 km when we may have an opportunity to look first at 20,000 km. This fact plays against the fact that if a search is necessary, many fewer degrees of sky must be searched at the longer range because the same amount of orbital uncertainty is a greater number of degrees of sky when the object is moving faster. Hence we would

really like to look for an object never seen before (or whose position is uncertain) when it is signal/noise detectable but moving relatively slowly and hence requires a smaller search volume. The program presently says that if an object is beyond 7.5 earth radii ($\sim$48,000 km) and it gets closer than 7.5 earth radii (at perigee) wait to schedule it. While there are obvious pathological cases such that a satellite with a given orbit could never be scheduled (or at least not for several days or weeks) no such satellites have been found in reality.

The area of detectability is one of concern to us and should be of concern to any GEODSS contractor.

TROUBLESOME SATELLITES

The Dynamic Scheduler is designed to provide reasonably good detection probability for most satellites (say 90 percent - 95 percent). There are, however, several objects in the SDC catalog whose reflection properties are such that they should only be attempted during a small time (or true anomaly or orientation, etc.) window. There are also those which can be seen by few other sensors and hence it is important to have as much orbit coverage as possible in the metric data. These objects should be handled manually, outside of the routine schedule. To expect a computer program to properly schedule them would mean adding greatly to its size and complexity.

CONCLUSIONS

The ability to schedule satellite observations dynamically has been demonstrated. The advantages of such a scheduling algorithm over static scheduling have been presented. Some problem areas, especially with regard to detectability have been discussed. The need for special handling for certain satellites has been pointed out.

ACKNOWLEDGEMENTS

My thanks to G. T. Flynn for inspiring the program and to F. P. Richichi for pointing out that difficult judgment decisions can become the obvious once the proper path is chosen.

CONCLUSIONS

The ability to schedule satellite observations dynamically has been demonstrated. The advantages of such a scheduling algorithm over static scheduling have been presented. Some problem areas, especially with regard to detectability have been discussed. The need for special handling for certain satellites has been pointed out.

APPENDIX

The various weighting factors and the equations used in their computation are presented below.

Parameter		Weight
Status: active		.5
Status: not active		2
Status: unknown		1
Observed	$\mathrm{MIN}(.5, \frac{1}{1 + .1(T)})$	Where T = MAX(0, time since last observation minus three days)
Unobserved	.5	
Epoch	$\mathrm{MIN}(.5, \frac{1}{1 + .1(\gamma)})$	Where γ = MAX(0, age of epoch minus ten days)
Elevation Rate	1/e	Where e is minus the elevation change over the next ten minutes. If $e < 2$ the weight is set to 1

Satellites which are not geosynchronous are not scheduled unless their elevation is at least 20 degrees. Synchronous satellites will be scheduled down to an elevation of 12 degrees. Below that elevation the operator is warned that the satellite cannot be scheduled. Objects are not scheduled when their sun/sensor/satellite included angle is less than 100 degrees, when the viewing angle of the satellite is within 30 degrees of the viewing angle of the moon or when the range to the satellite exceeds 7.5 earth radii and its perigee is less than 7.5 earth radii.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-77-176	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Dynamic Satellite Scheduling Algorithm		5. TYPE OF REPORT & PERIOD COVERED Project Report
		6. PERFORMING ORG. REPORT NUMBER ~~Project Report~~ ETS-15
7. AUTHOR(s) William J. Taylor		8. CONTRACT OR GRANT NUMBER(s) F19628-76-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 63428F ~~Project No.~~ 2128
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 7 July 1977
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

satellite detection
orbit determination
GEODSS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer program to dynamically schedule satellite observations has been installed and tested. The principle of the program is to apply weighting factors for each of several pertinent criteria to the angular distance between the current telescope position and the current predicted position of each satellite in a predefined list. Initial tests showed favorable results with few large displacements of the telescope. The program executes in 5-7 seconds of shared real time for a typical mix of about one hundred satellites.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 18 6 9 14 10 15 16 12 20p. 11

207 650

LB